

**WRAP Integrated Geospatial
Information Management Strategy (WIGIMS)**

***Geospatial Information Management Strategy and
Implementation Recommendations Report***

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1.0 Introduction

The WRAP Integrated Geospatial Information Management Strategy (WIGIMS) project is designed to analyze WRAP's geospatial information and related decision support needs, and then plan for the development of WRAP's capability to fulfill its mission by fully leveraging existing and emerging geospatial information, standards, technologies, and applications in an efficient and integrated manner. The project will result in a strategy for developing a spatial data infrastructure (SDI) that meets the needs of WRAP and its user community. This infrastructure will provide the means to discover, evaluate, and/or access the emissions, monitoring, and modeling data related to air quality and visibility for the WRAP user region, and facilitate integration of these data for use in custom tools or applications. In doing so, WRAP's ability to provide the data and technical and policy tools to its clientele - state and tribal members, federal land managers, committees, forums, and all other interested parties - as well as to its own staff, will be improved both in the short- and long-term.

The WIGIMS project consisted of three phases: Needs Assessment, Resource Inventory, and Strategy Development, all critical in developing an infrastructure that will meet the present and future functional requirements of WRAP staff and its clientele. After completing the Needs Assessment phase, Pangaea Information Technologies, Ltd. directed its attention to documenting all of the potentially useful and/or essential resources that exist or are planned to be available to meet the geospatial needs as identified by WRAP staff and the Needs Assessment participants. After collecting information in regards to all of the major geospatial resources available to WRAP, integration strategy options were developed.

The overall objective of this report is present, evaluate, and make specific recommendations on realistic strategy options that facilitate and provide for:

- 1) The interoperability of information systems within WRAP and those systems outside of WRAP that are germane to its user community to the extent that discovery, evaluation, and access to data and information is facilitated for the short- to mid-term,
- 2) The integration of existing and forthcoming emissions, monitoring, modeling, and analytical products of these three primary data sets in conjunction with contextual data for use in both visualization and computational tools, and
- 3) Participation in a longer-term process – continuing to develop a WRAP Spatial Data Infrastructure – that will ensure that WRAP products are discoverable and accessible, and that WRAP users will be able to easily discover, evaluate and access all types of the “best available” contextual information into the future.

It is important to note that this project is designed to produce strategy options for development of an *infrastructure* that provides access to integrated datasets and/or facilitates the integration of those datasets. It does *not* attempt to design or recommend *specific tools or applications* that support the particular needs of WRAP users, but rather to generate and evaluate options that, when implemented, would provide a robust platform upon which those tools and applications could be built.

This report is the third in the series of three WIGIMS publications, and is preceded by a *Needs Assessment Report*, and the *Resource Inventory Report*. Preliminary results of the WIGIMS project were presented at the Technical Oversight Committee meeting on 13 May 2004.

2.0 Executive Summary

The WRAP Integrated Geospatial Information Management Strategy (WIGIMS) *Needs Assessment Report* phase confirmed the *a priori* assumption that WRAP users need access to integrated emissions, monitoring, modeling, and auxiliary geodata. For organizations such as WRAP with both distributed geospatial data providers and users, an excellent option for making the geodata accessible is through a known, flexible platform upon which custom tools and applications can be built. At a minimum, the needed access services available from that platform should include web-mapping for visualization and other interfaces that provide standardized data streams. Other basic and essential services – those that facilitate discovery and evaluation – should also be built from this platform.

In order to support this need, development of a WRAP spatial data infrastructure (SDI) of some type is required. A SDI is an integrated, on-line network that delivers geospatial data, services and information for applications, better business and policy decision-making, and value-added commercial activities. There are three primary components to an SDI:

- **Organizational commitment** and arrangements to stand-up and build upon spatial data and services within a heterogeneous community of producers and users
- The **spatial information**, and its integration
- **Technologies, standards, specifications** for discovery, visualization, and use of primarily digital geographic information

WRAP has extensive geodata resources available for developing its own spatial data infrastructure, as documented in the WIGIMS *Resource Inventory Report*. At present, the fundamental **spatial information** components are already in place in the form of dataholdings at the EDMS, VIEWS, and the RMC as well as from the CoHA and Near projects. In addition, a wealth of ancillary geodata is available through the US, Canadian, and Mexican spatial data infrastructures. Finally, the large set of integrated datasets accessible through DataFed, which are relevant to the air quality management community, are all potentially available for incorporation into a WRAP SDI.

At present, the fundamental emissions, monitoring, or modeling information has not been made broadly available to the WRAP user community in an integrated manner. The limitation is not technological in nature: WRAP has access to a body of **technologies, standards, and specifications** that can enable discovery, evaluation, and access of its spatial information resources, and support for their implementation. To date, the standards and specifications have not been adopted at WRAP's "data nodes" (i.e., EDMS, VIEWS, RMC, and the CoHA system site at DRI), nor have policies or arrangements been put in place to promote geospatial interoperability. Currently the burden of standardization and integration falls on the WRAP user community.

This document, after reviewing WRAP user needs, explores background information germane to WRAP's geospatial interoperability needs including: SDIs, levels of geospatial interoperability, interoperable web services, types and levels of data integration. WRAP resources are then reviewed in this new light, and strategy options are developed with the primary goal of *building a platform from which data – integrated at the computational level – and other information is made available to WRAP's users in easily ingestible forms from easily accessible interfaces*. Twelve specific system- and user-level goals are introduced, in addition to system cost and time-to-implementation. These goals are used to evaluate the different system options.

Only technologically feasible and economically practical options are considered. From a geospatial interoperability and data integration standpoint, these options differ primarily in who is responsible for adhering to the interface specification (i.e., the standardization step), and who does the integration. They are as follows:

- The “status quo” option – included to evaluate the current distributed WRAP geospatial information management situation, as well as serve as a basis for comparison.
- The “centralized” option – the content of the WRAP data nodes is consolidated with standardization and integration performed at a new location or at an existing WRAP-controlled system (i.e., EDMS or CoHa-DRI) with some modification and/or augmentation.

In addition to the “status quo”, two other “distributed” options are defined and evaluated:

- The “provider standardization” option – same as the status quo with the WRAP data nodes tasked with standardization, and WRAP users still responsible for integration, albeit facilitated to some degree.
- The “mediated standardization and integration” option – in which a third party performs the homogenization and integration services.

The evaluation results, aggregated for the (7) system- and (5) user-level criteria, are:

Evaluation Criteria	Status Quo	Centralized			Distributed w/ standards imposed on data providers	Distributed w/ data mediator
		New	Hosted at EDMS	Hosted at DRI		
System Properties	2.4	2.7	2.8	2.3	2.6	3.3
User Needs	1.5	3.3	2.8	2.7	2.3	3.8
Costs	3.5	1.3	1.8	1.8	2.8	3.8
Implementation Timeline	4	2	2	2	2	4

Where: D (1) = poor C (2) = fair B (3) = good A (4) = excellent

On the basis of this evaluation, the “mediated standardization and integration” option is recommended. Additionally, a basic but extensible WRAP Geospatial Information Portal (GIP) is recommended which would feature discovery and evaluation tools for the geodata content offered to WRAP users, as well as open, standard interfaces through which the content could be accessed. The resulting infrastructure would serve as the platform from which user-defined tools could be built, either with SCOTS (standards-based, commercial off-the-shelf software) or custom applications. Two other primary recommendations are made: 1) take a phased approach, and 2) identify a WRAP Geospatial Information Management Program Coordinator to work with a Geospatial Information Management Technical Working Group to perform a number of low-cost and low-risk – but effective – tasks which promote geospatial interoperability and efficiency and are identified at the end of this report.

3.0 Background

3.1 Scope of Final Report

This report will:

- 1) summarize the user needs and the resources available¹ to WRAP as they relate to geospatial data and information and the visual as well as computational integration of that information,
- 2) present and discuss guiding principles and system design goals
- 3) present and discuss realistic system options available to WRAP
- 4) present and discuss evaluation criteria, based on the design goals
- 5) examine and evaluate each option
- 6) recommend option(s)
- 7) recommend other actions to meet specific integration and interoperability goals

This project was not designed to develop a specific system design diagram, nor a comprehensive implementation plan. To the greatest extent possible, this report will present a set of specific actions that can be taken to efficiently improve geospatial data and information integration for the WRAP user community.

3.2 WRAP Needs

3.2.1 User Needs

The user needs survey results can be distilled down into 4 primary points:

- 1) The responses to several questions provided concrete evidence that a large number of WRAP-supported users need access to integrated geospatial emissions, monitoring, and modeling information. These responses are included in Table 1, below.

Response (x/15)	Data/Layer Type	Description	Examples
14	Emissions	Pollutant sources	Point Sources (e.g., stacks)
			Mobile Sources (e.g., semi-tractors)
			Area Sources (e.g., agricultural land, prescribed burns)
13	Monitoring and Data Analysis	Pollution-level measurements and analyzed data	Stations with depositional fluxes
			Networks with pollutant concentrations in ambient air
			Interpolated pollutant concentration surfaces
			Time series of visual impairment
15	Modeling output	Pollution estimation for areas (usually gridded / raster).	Pie charts of pollutant species
			Source apportionment
			Dispersion from source(s)
			Control strategy scenario analysis

¹ Rather than repeat large portions of the *Needs Assessment Report* and the *Resource Inventory Report*, the reader is directed to those documents for more detail.

- 2) Access to integrated ancillary (i.e., contextual) geospatial information is also required to improve understanding of the 3 primary data types. The specific responses are included in Table 2, below.

Response (x/15)	Data/Layer Type	Description	Examples
12	Administrative boundaries	Linear features enclosing legally-defined areas	Political – State of Nevada
			Regulatory – Class I Areas
			Reservations
			Public lands
13	Atmospheric &/or surface conditions	Meteorological measurements or climatological settings (specific to a point or area for a time or period)	30-year normals, 10-year means
			Palmer Drought Severity Index
			Relative humidity
13	Transportation networks	Linear features used for travel	Road network
			Railroad network
			Shipping lanes
13	Census data	Areas with linked population and demographic info	Population density by County
			Mean # autos per household, by Tract
			Type of heating, by Block-group
13	Elevation	Measurements above mean sea level	Shaded topographic relief
			Hypsography – “topo lines”
			Digital Elevation Models (DEM)
13	Land use / cover type	Area features with the same land use or land cover.	Urban or built-up
			Row crops
			Pasture / feedlot
			Tree species composition
3	Hydrography	Linear or polygonal water features	Oceans
			Lakes
			Rivers
10	Imagery	Remotely-sensed information from aerial or satellite platform	Landsat-TM
			IKONOS
			Orthoimagery

- 3) Users require a diverse set of spatial and temporal aggregation levels; *flexibility* should be maintained by providing for user-defined levels of data aggregation.
- 4) A geospatial data infrastructure is needed and should support non-proprietary application and tool development including web-based graphical interfaces that allow user-defined selection and download of feature sets, and the capability to integrate user-owned data with the datasets described within this survey.

In addition to the above summary of the Needs Assessment, two important points regarding that report should be reiterated. First, 4 of 15 users responded that integrating monitoring, emissions and modeling output was of “high” or “critical” importance to their mission and that over “50 users/month” (each mission) would access the integrated datasets. The second, albeit regrettable, point is that although the needs assessment did solidify the *a priori* assumption that integration of these primary WRAP geospatial databases is essential, the exact level of integration was not fully elucidated and the participation in the survey (15 respondents) does not warrant highly specific actions (i.e., to address specific use cases) at this time. This latter point will be revisited in the Evaluation Criteria section and Recommendations section of the report.

3.2.2 Geospatial Interoperability Needs

3.2.2.1 Spatial Data Infrastructures – A primer

Knowingly or not, WRAP has been assembling many of the components of a spatial data infrastructure (SDI). A *spatial data infrastructure* is an integrated, on-line network that delivers geospatial data, services and information for applications, better business and policy decision-making, and value-added commercial activities. An SDI has the following components:

- Organizational commitment and arrangements to stand-up and build upon spatial data and services within a heterogeneous community of producers and users,
- The spatial information, and its integration, and
- Technologies, standards, specifications for discovery, visualization, and use of primarily digital geographic information.

An SDI has the following objectives:

- To promote access to and usage of digital geospatial information of value to multiple users,
- To improve discovery of and public access to primarily governmental geospatial data resources, and
- To reduce duplication of effort among collaborating organizations developing, publishing and building applications on geospatial data and services.

SDIs currently are being developed at the state, national, and international levels. The existing SDIs that are relevant to WRAP are the US National Spatial Data Infrastructure (NSDI) and the Canadian Geospatial Data Infrastructure (CGDI). Mexico's SDI development efforts are coordinated through the Instituto Nacional de Estadística, Geografía e Informática (INEGI, <http://www.inegi.gob.mx>).

The important point to remember is the adoption of open standards and specifications and accessible solutions are essential for the successful participation in and operation of a spatial data infrastructure (SDI). US national standards are required for the NSDI to work effectively, with participation by states, tribes and other user communities, such as WRAP. Similarly, international standards are required for full participation in and operation of the Global Spatial Data Infrastructure (GSDI). **The extent to which WRAP is committed to making its SDI effective and meeting the above objectives is tied directly to the awareness of its needs and an understanding of the opportunities for geospatial interoperability to enable discovery, evaluation, and access functionality.** The good news is that these specifications and standards have already been developed and many are already in use by several data providers frequented by WRAP users and for WRAP projects. Moreover, there is a growing community devoted solely to facilitating the successful development of new and emerging SDIs.

3.2.2.2 Levels of Geospatial Interoperability and WRAP

Geospatial interoperability is the capability to communicate, execute programs, or transfer spatial data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units. Bishr² (1998) identified six levels of interoperability for geographical information systems (GIS), as presented in Figure 1 (below).

² Bishr, Y. 1998. Overcoming the semantic and other barriers to GIS interoperability. *Int. J. Geographical Information Science* **12**(4):229-314.

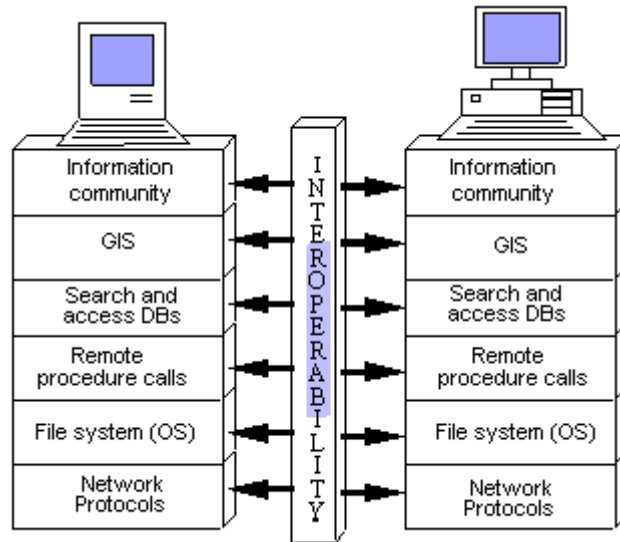


Figure 1: Levels of geospatial interoperability. Based on the figure in Bishr (1998)².

At present most of WRAP’s user community, as do most information communities, operate somewhere around the fourth level of interoperability. The opportunity exists to solidify interoperability at that level and move the organization and its users to the fifth level of interoperability. Given that WRAP geographic information users operate within the same information community – air quality science and management, the opportunity exists to move to the highest level of geospatial interoperability through the development and use of controlled vocabularies, and by carefully describing data applications within the business processes and operations of each user group using some standard, e.g., via unified modeling language (UML).

3.2.2.2 Web Services and the General Service Model

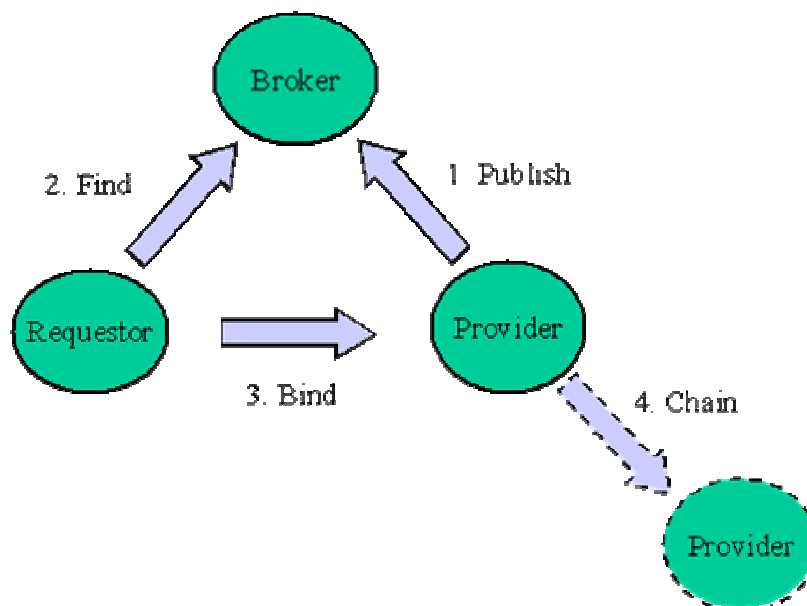


Figure 2: OpenGIS Consortium (OGC) General Service Model

If the reader is already familiar with the above figure, you can skip down to the web service definition in this section (bottom of this page), so long as you already understand the importance of metadata and service directories to the operations.

As shown [above], there are three essential kinds of operations performed by services:

Publish - The publish (and unpublish) operation is used to advertise (or remove) data and services to a broker (e.g., a registry, catalog or clearinghouse). A service provider contacts the service broker to publish or unpublish a service. A service provider typically publishes to the broker metadata describing, for example, its capabilities and network address.

Find - Service requestors and service brokers collaborate to perform the find operation. Service requestors describe the kinds of services they're looking for to the broker and the broker delivers the results that match the request. Service requestors typically use metadata published to the broker to find service providers of interest.

Bind - The bind operation takes place between a service requestor and a service provider. The two parties negotiate as appropriate so the requestor can access and invoke services of the provider. A service requestor typically uses service metadata provided by the broker to bind to a service provider.

And one optional operation:

Chain - The chain operation binds a sequence of services where, for each adjacent pair of services, occurrence of the first action is necessary for the occurrence of the second action.

The General Service Model (GSM) distinguishes between service description and service implementation. This allows service requestors to bind to a specific implementation of a service provider at development time, at deployment time, or dynamically at runtime. The GSM uses service descriptions (i.e., metadata about services) to support Publish, Find, Bind and Chain operations. Service metadata plays three distinct roles in the GSM:

1. Metadata specifies the characteristics of a service provider. Service brokers use these characteristics to categorize service providers to support the find operation. The classification of services can be based on one or more hierarchical service taxonomies. Service requestors use these characteristics to match a service provider to their requirements.
2. Metadata specifies non-functional characteristics such as security, transactional requirements, cost of using the service provider, and others. Non-functional characteristics may be used to help a service requester find a service provider.
3. Metadata describes the interfaces used to access the service. The interface description includes its signature, allowed operations, data typing, and the access protocols. Service requestors use this information to bind to the service provider and invoke its services using the published interfaces.

A Web Service is a network-based, distributed, modular component that performs specific tasks, and conforms to a specific set of technical specifications that make it interoperable with compatible components.

Please note that both the figure and the remaining text in this section were extracted from: <http://www.intl-interfaces.com/servicemodel/gsm/gsm-2001-08-15.html#TheBasicServiceModel>, which describes the OpenGIS Consortium General Service Model.

Examples of web services include data clearinghouses or gateways, web mapping services, and re-projection (coordinate transform) services. Again, spatial data infrastructures operate efficiently if users agree upon and adhere to *open* technical specifications. A final diagram, figure 3, is presented in this section, without discussion, so as to provide a reference for the service-level specifications (e.g., OGC WMS) that will be mentioned in relation to WRAP's user needs in subsequent sections of this report, and possibly satisfy the appetite of the more development-oriented reader. For more information, please see the web link above and/or the *OGC Reference Model (ORM)* (<http://www.opengis.org/specs/>) and the *Geospatial Interoperability Reference Model (GIRM)* (<http://gai.fgdc.gov/girm/>).

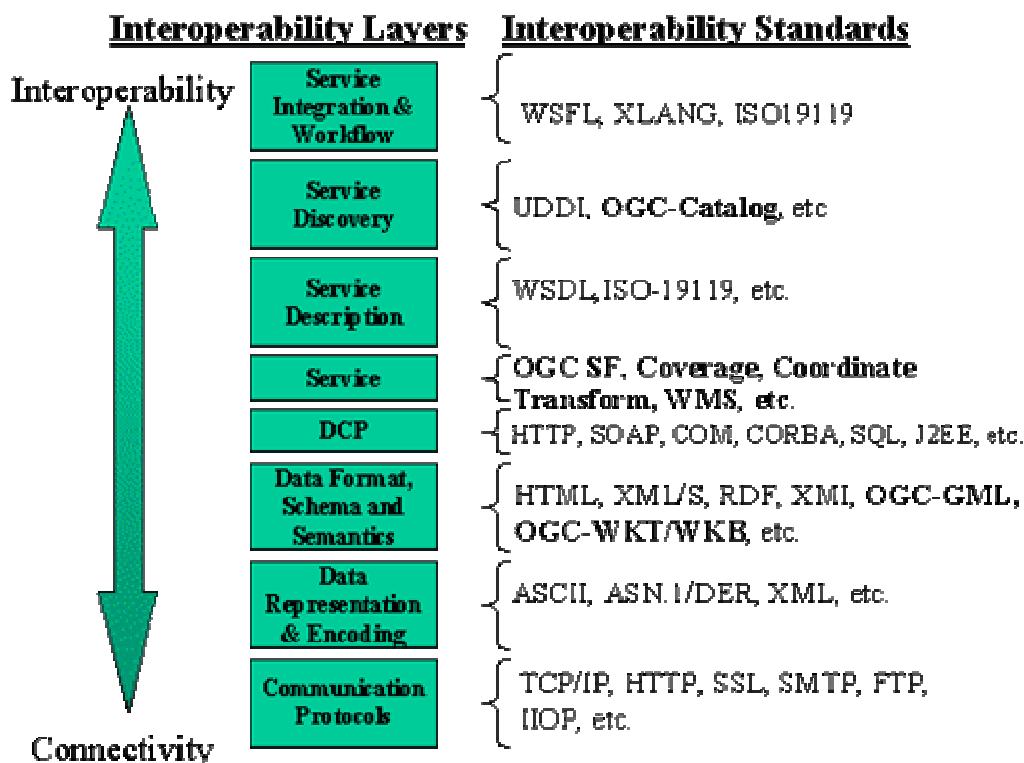


Figure 3. Services Interoperability Stack

3.2.3 Types of Geospatial Information Integration and WRAP

The WRAP user community has expressed needs for geospatial data integration on several different levels, and these must be defined before discussing strategies, current capabilities, and costs.

Traditional geospatial integration can be divided into three separate categories, that performed at the level of the dataset for the geographic features – vertical and horizontal integration, and that performed for data tables associated with the features – attribute integration:

Vertical data integration consists of two primary tasks, standardizing the projection (including the datum and associated spheroid), and selecting data sets with the same fundamental scale. Current web-mapping technologies to some extent provide for both: i) on-the-fly standardization of projection (re-projection), and ii) specification of viewing scale of the data sets. While this first

provision is largely automated, the second requires more planning and decision-making and is dependent on the availability of data sets that are either of the same scale or are hierarchical in nature and can be displayed according to careful selection of the appropriate “level.” (This latter action influencing horizontal integration needs, decisions, and actions.)

Once vertical integration is provided for, then detailed horizontal integration can begin. Transboundary horizontal integration for vector data with line or polygon features normally involves addressing discrepancies such as offsets, discontinuities, and differences in feature density. These discrepancies are due to differences in dataset production date, feature identification and classification systems, data quality and associated errors, or in fundamental data set scale (which strongly influences feature density).

Attribute integration is also necessary, especially when subsets of hierarchical datasets (e.g., road networks) are being horizontally-integrated across geopolitical boundaries. In such cases where data standards are non-existent or not have not been adopted, the development of crosswalk tables and supporting documentation that address semantic differences and assumptions is essential in ensuring the potential for full integration of the datasets and consistency in portrayal. However, even when these issues are addressed, the consistency of portraying different data sets of a particular thematic type across administrative boundaries requires careful consideration. Fortunately, a relatively new specification from the OGC, the Style Layer Descriptor (SLD) enables this level of interoperability and consistency. Moreover, tools for site developers employing the WMS specification also now facilitate the incorporation of the SLD specification.

The primary datasets that WRAP deals with adds, quite literally, another dimension of integration to be addressed – that of the temporal domain. The time integration of geospatial information with time series encoded in 1) attribute values, 2) as values of separate attributes, or 3) as separate datasets in a data series must be addressed and provided for. Here too, the geospatial information interoperability standards community provides an interface (OGC Web Coverage Service) and data format specification (Geographic Markup Language, or GML, an extension of the parent XML) which handle time series for point, line, polygon, lattice, and raster data.

Another aspect of data “integration” should be mentioned here, in relation to the above discussion of interoperability of web service interfaces. WRAP users need geodata that is integrated to either of two levels, defined by functional requirement of the requisite application:

- 1) visual integration – simple visualization, i.e., looking at images of the primary and ancillary data layers in the same or adjacent frames, and/or
- 2) computational integration – which allows for quantitative analyses to be performed with two or more primary and/or ancillary datasets.

As expressed in Figure 3, there are several specifications that must be employed to achieve the interoperability required to provide either level of data integration. For the purposes of this report, and with respect to *open* geospatial interoperability standards, only the OGC WMS specification will be referred to when discussing the need for visual integration within web-enabled GIS software interfaces, and the OGC WFS (or WCS) and GML when discussing the need for computation-level integration for GIS interfaces and data encoding schemes, respectively.

It should be explicitly stated that the level of integration necessary to allow simple visualization of two datasets in a web-mapping application (irrespective of the use of the WMS spec), does not necessarily mean that these datasets have been integrated at a level necessary for computational analysis. Although a picture (e.g., image) may be worth a thousand words, and could address some binary question (e.g., is the level of air quality within the legal limits?) or categorical question (e.g., what is the predominant landuse surrounding the IMPROVE sites with elevated OC levels?), those questions could not be easily answered in an automated fashion (i.e., harnessing the power of GIS), nor could the information contained therein be made available for rigorous statistical analysis. This is not the case in the reverse situation, given existing geospatial technologies: if two datasets have been integrated to the “computational-level”, then generally they are available for visual integration. Hence, for the purposes of this report, visual integration is defined as a fundamentally lower level of data integration than computational integration.

3.3 WRAP Resources: Data, Portals, Mediation Services, and Standards

The primary spatial extent of the data resources under consideration is the WRAP region, consisting of the 14 member states and many tribal areas. Data resources for bordering US regions (i.e., pertaining to the CENRAP region) and Canada and Mexico must be accounted for in modeling and planning activities. The temporal extent of the data resources include the historic records of emissions, monitored and modeled air quality, and meteorological parameters, as well as modeled forecasts, emissions, and air quality scenarios for the future.

Discussion of the different types of geospatial information resources available to WRAP is partitioned into data providers, data portals, data mediation services, and the organizations responsible for setting the open standards which enable geospatial interoperability. At the conclusion of this section, a summary of the information is provided in Table 3.

3.3.1 Data Providers

There are three primary “geospatial data nodes” that support WRAP activities:

- 1) the Emissions Data Management System (EDMS),
- 2) the Visibility Information Exchange Web System (VIEWS), and
- 3) the Regional Monitoring Center (RMC).

Given its voluminous warehouse of ancillary geodata and synthesized information products from the above and other resources,

- 4) the Causes of Haze Assessment Project (CoHA)

could be considered a WRAP data node.

Other existing geospatial information is available from the NEAR project webpages, with future content to be made available from the Attribution of Haze Project.

At the present time, none of the above data is being published through web services that adhere to the geospatial interoperability standards (WMS/WFS/WCS) associated with web interfaces, nor are these services a part of stated development plans.

Producers of the fundamental ancillary geodata (e.g., transportation, hydrography, administrative boundaries, elevation, remotely-sensed imagery, geographic names, and land cover layers) include the USGS, and other federal and state³ sources. By design, The National Map (USGS), the “geospatial content” component of the NSDI, integrates the best available state and local geodata into its national-level geospatial fabric. The National Map is committed to geospatial interoperability standards, with OGC-compliant web-mapping services available, and is planning to offer WFS/WCS capabilities within the next year or so.

3.3.2 Data Portals

Data portals provide the discovery service component of a spatial data infrastructure and often provide evaluation tools, through access to metadata and web-mapping services for data visualization. Portals also normally provide direct linkages to the data producers and service providers through the online location (i.e., URL) specified in the metadata. The set of data products and services are stored in a registry and published in a catalog. At the national-level two particular portals should be made known to the WRAP user community: Geospatial One-Stop, the official portal for the federal government which utilizes the National Map web-mapping tool, and The Geography Network, which is administered by a private sector entity. Both of these portals, and particularly Geospatial One-Stop, have adopted and utilize the standards and specifications offered through geospatial interoperability standards organizations (see below).

Within the WRAP information community – that pertaining to air quality management, at least two portals are available. The first is the catalog offered through the VIEWS website. Although VIEWS makes some of its data, particularly the IMPROVE database, accessible through a number of formats and web services, recent discussion with the VIEWS development staff and administrators indicated that adherence to the aforementioned open geospatial interoperability specifications is not planned now, nor will it be in the immediate future.

The second catalog of interest to the air quality information community, and thus WRAP, is that offered through the DataFed.net website. The suite of emissions, monitoring, modeling, meteorological and climate, satellite imagery, and other ancillary data registered there is particularly noteworthy given the level of integration offered through DataFed and its interest in open geospatial interoperability standards.

3.3.3 Data Mediators

In addition to its role as a portal, DataFed offers data mediation services and employs the use of a “virtual global data model”, offering the *possibility* of a fifth level of geospatial interoperability and invaluable services for those who join its ranks, including the WRAP user community. None of the data for which DataFed provides discovery, evaluation, and access services is unique. All of its data can be accessed through its primary online source. The uniqueness of this resource lies in the homogenization and ingestion of the participant’s data into the DataFed virtual database, or physical database in certain cases. The homogenization is performed through the use of data wrappers, which are essentially translation code. These wrappers enable vertical (geospatial) and temporal integration of the producers’ datasets, subsequently accessible through one single location but still actively linked to the data steward for additions (in accordance with the fundamental time-step of the respective dataset) and updates associated with normal data maintenance.

³ See listing on CoHA website, http://coha.dri.edu/web/general/cohadata_stategisdata.html.

The DataFed “Data Viewer” is similar to the VIEWS application in that the interface contains a time-series graph that is linked to the spatial display both in space and time. Also, like the VIEWS application, DataFed.net provides a set of tools that can be integrated into the Data Viewer. These include back trajectory analyses (CATT and Kitty) and a “Plume” tool that shows dispersion from a user-defined location (by clicking on the map within the Data Viewer). The view can be saved as a .gif image, as XML that includes the URL that can be “imbedded” into user-defined applications or web-pages.

Notably, the CAPITA group at Washington University (St. Louis, MO), who administers and has been the primary developer of DataFed, views the participation in and by other segments of NSDI user community as mutually beneficial. As such, a OGC-compliant Web Mapping Service (WMS) has recently been added. Although this capability is still under development, this service will eventually allow all of the data in the Catalog to be displayed with standard GIS software packages and web-mapping products that provide OGC connectors (e.g., ESRI ArcMap, ArcExplorer, ArcIMS, etc. and Autodesk MapGuide, UMinn MapServer). Recent discussions with the CAPITA group indicate a willingness to explore the possibility of adding WFS and WCS capabilities to the web services it now offers. This is significant in that it would make accessible a GML stream of temporally and spatially data, integrated at the “computational level”, through a standard service interface.

CAPITA also recognizes limitations associated with its Viewer functionality and some its existing data formats. For example, some of its line and polygon information associated with reference layers (i.e., US States boundaries) is available for viewing only as image overlays, posing problems with portrayal at different scales. However, this does not change the real value of this resource – the mediation services offered for a wide range of emissions, monitoring, modeling, etc., datasets. Certainly, some additional development work would be necessary to integrate WRAP’s primary datasets and make these available for ingestion at the computation-level (as discussed above). Nonetheless, **the discovery, evaluation, and access services for a significant number of useful datasets already offered through the DataFed represent an unprecedented geospatial information resource for the air quality community, and once the OGC-compliant interfaces are fully implemented, especially so for any community sector interested in higher levels of geospatial interoperability.**

Another potentially important data mediation service is the EPA’s Central Data Exchange (CDX) Network. As early as March 15, 2002, CDX developers expressed encoding to GML as a user need⁴, though its current development status not fully known. If this service were offered, it could be significant for WRAP given that the Phase II development of the EDMS includes publishing its data holdings through the CDX Network services⁵.

3.3.4 Geospatial Interoperability Standard Organizations

The final type of resource that should be brought to the attention of WRAP is the policy and standards-setting bodies related to geospatial information interoperability. The OGC has been touched upon already. The Federal Geographic Data Committee (FGDC) should be mentioned by name, though the reader is directed to the Resource Inventory report for more detail about this organization and its activities.

⁴ See www.web-services.gov/XML%20Web%20Services%20March%2015,%202002.ppt, page 17.

⁵ WRAP might consider asking that the CDX publish the GML through a standard web service interface, e.g., WFS.

Table 3: A summary of the geospatial information resources available to WRAP.

Resource Name	Resource Type	Content &/or Tool / Application Type	Web Delivery Format	*Adherence to Standards?	Web Service Development Staff?	Current Funding for WRAP Activities (% of total)
EDMS	Data Provider; Tools / Apps	Emissions; User-defined exports, SVG-based web-mapping	Data Files; Map images	No	Y	100; on-going
VIEWS	Data Provider; Tools / Apps	Monitoring; User defined exports; web-mapping	Data Files; Graphics; Services	No	Y	20; on-going
RMC	Data Provider	Scenario and Model Output	Data Files; Graphics	No	?	100; on-going
CoHA	Data Provider; Tools / Apps	Analysis Output; Ancillary Data	Data Files; Images; Graphics	No	?	75; on-going
ITEP	Data Provider	Tribal Boundaries; Demographics	Files upon request	No	N/A	unknown; on-going
The National Map	Data Provider Tools / Apps	Web-Mapping; Seamless Data Server	Files, Services & Documents	Yes; All	Y	0
CAPITA / DataFed	Data Mediator; Tools / Apps; Web-services	Emissions; Monitoring; Meteorological; Analysis Output; Web-mapping; Re-usable components	Images and graphs;	Yes: WMS, WFS, WCS.	Y	unknown; (\$40k per year through the Inter-RPO)
GOS	Tools / Apps	Portal	Documents and links to content	Yes; All	Y	0
FGDC	Standards; Policy; Support / Reference; Tools / Apps	Clearinghouse Network; Metadata tools; Metadata standards and profiles.	Services and Documents	Yes	Y	0
OGC; ISO	Standards; Reference			N/A	N/A	0

*"Adherence to Standards" refers specifically to existing or planned compliance with federally-adopted (FGDC) or commonly used standards (OpenGIS Consortium, i.e., OGC) that provide for geospatial interoperability in describing content (e.g., FGDC-STD-001-1998 [CSDGM], ISO-19115) or delivering that content over the Internet as map images (e.g., OGC WMS 1.1.1) or as feature-level (points, lines, polygons, rasters, lattices, n-dimensional matrices, etc) data packages (e.g., OGC WFS 1.0, OGC WCS 1.0).

4.0 Strategy

4.1 Guiding Principles and Design Goals

Prior to discussing specific design criteria for the WRAP spatial data infrastructure, the simple vision of open access for geospatial information based on *discover*, *evaluate*, and *access* schema should be explicitly stated:

- Discover information in response to need
- Evaluate relevant spatial information
- Link to spatial data through description
- Establish connection to “map” servers to display data remotely
- Provide direct access to remote data for analytical use in “distributed GIS”

This simple model contains most of the design considerations elements discussed to this point in the report. In designing the architecture for a WRAP SDI, not all future needs or applications can be anticipated. Hence, an open and flexible architecture should be of primary importance. Our overall goal should be to:

- Build a platform from which data – integrated at the computational level – and other information is made available to WRAP’s users in easily ingestible forms from easily accessible interfaces.

The following design goals – grouped into system-level, user-level, cost, and time categories – were considered in developing different architectural options for the WRAP SDI:

System-level Goals

- 1) Flexible – design a system that can adapt to new and evolving technologies, standards, and changes in WRAP’s mission.
- 2) Extensible – construct system for which it is easy to add capacity, components, and to extend system for unanticipated uses.
- 3) Stable – all else equal, select components that will remain in place and that are under your control, and are committed to WRAP objectives.
- 4) “Phase-able” – if not 100% certain of future needs or system tenability, select a system for which an incremental (phased) approach can be taken so as not to “put all of your eggs in one basket.”
- 5) Easy to Maintain – design system to keep the data in the hands of the data stewards, and access the data dynamically; follow the “*own what you must, access what you need*” credo.
- 6) Simple – design system to have less “breakable” links; keep system components to a minimum, especially those with unavoidable scheduled downtimes or prone to unscheduled interruptions.
- 7) Interoperable – system should promote connectivity between data nodes and other information networks through the use of open and accepted standards thus facilitating data sharing and reducing inefficiencies; system should not require the use of specific “brands” of hardware or software.

User-level Goals

- 1) Flexible – design a system that facilitates the production of all of the output types needed by users.
- 2) Inclusive and Comprehensive – consider the extent to which the system will leverage and encompass all existing resources including a diverse set of existing and planned data types and tools available through WRAP and other information communities.
- 3) Burden-less – design a system in which users are unencumbered with data integration tasks, and the number of connections necessary for discovery, evaluation, and (particularly) access operations is kept to a minimum.
- 4) Non-proprietary – system should not require the use of specific “brands” of hardware or software by users.
- 5) Effective – system should afford a computational-level of data integration.

Cost – all other things equal, the expense of the system should be minimized.

Schedule – all other things equal, the time that it takes for the system to become operational should be minimized.

4.2 System Architecture Options

The system architectures to be considered will include the following components:

- The three primary WRAP data nodes, and the CoHA node at the Desert Research Institute (DRI).
- WRAP project information.
- The resources available through DataFed.
- Data producers that participate in the NSDI.

Four basic types of system configurations will be considered as strategic options. Aside from the first option, the names of these options reflect the system-level approach, as *it relates to location of the data standardization and integration effort*.

- 1) *Status Quo*. As the name suggests, this system currently exists, and is presented as a baseline case for the dual purposes of evaluating the current system and for comparing with the alternatives. Clearly a distributed system, the integration burden is presently on the system users.
- 2) *Centralized*. This design option has several possible variations, three of which will be evaluated. In each of the three cases, a single database houses copies of all of the primary WRAP information and the synthesized information products from WRAP projects.
 - a) *Centralized – New*. This option takes the approach of establishing a new component system, connected to but standing apart from the other current WRAP nodes.

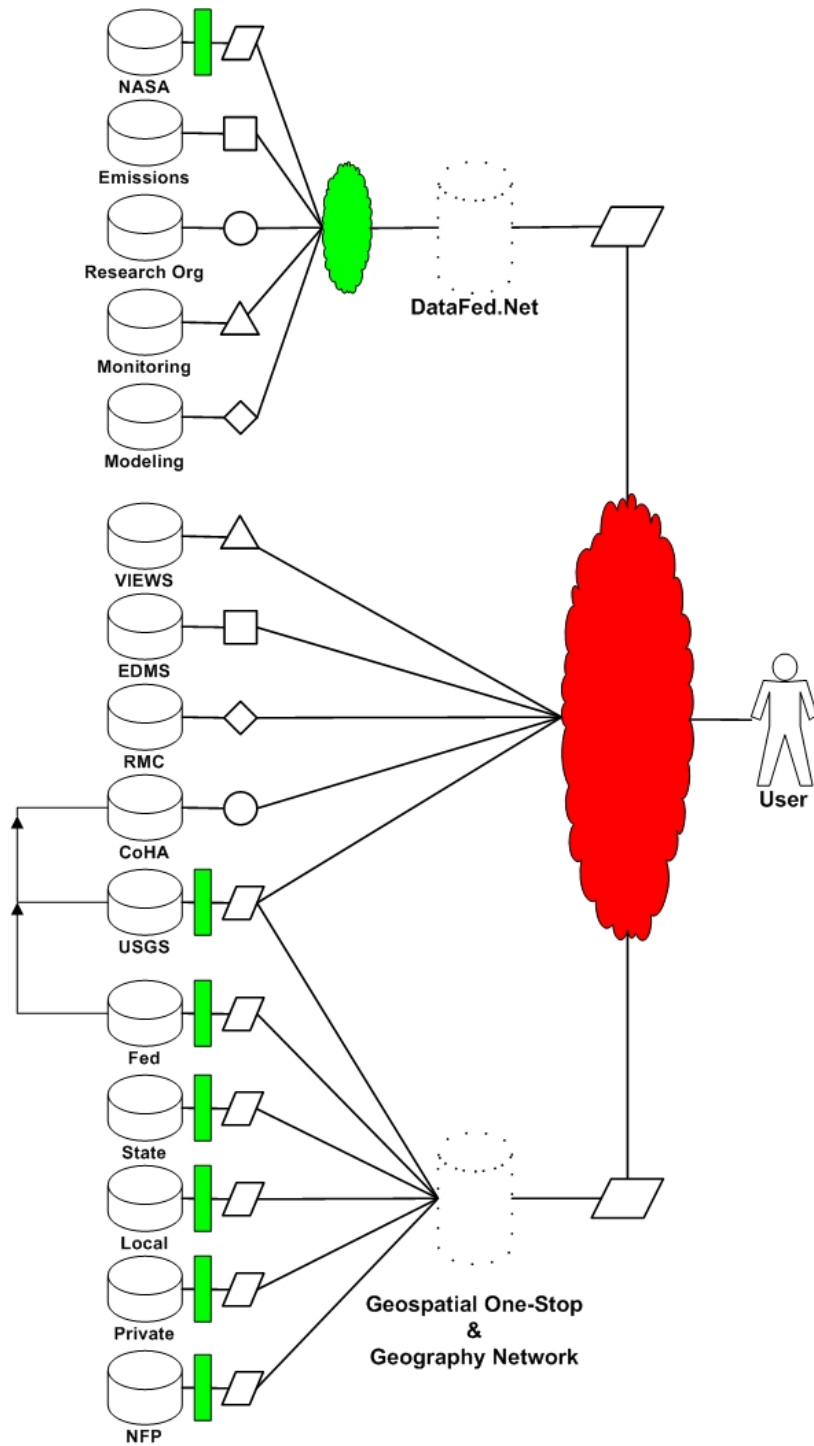
- b) *Centralized – EDMS*. This option takes the approach of leveraging the investment made in an existing system, in this case one that should in theory be extensible, and over which WRAP has complete control.
 - c) *Centralized – DRI*. This option also takes the approach of leveraging the investment made in an existing system over which WRAP has much control. In this case considerable costs for upgrading would be necessary.
- 3) Distributed – provider standardization.
 - 4) Distributed – mediated standardization and integration.

The figures that follow containing the following elements:

- The three primary WRAP data nodes and the CoHA node.
- Geodata available from NSDI participants, discoverable through Geospatial One-Stop.
- DataFed and generic examples of its data providers.
- A WRAP User.
- Different simple geometric shapes, each representing a different data format or file type.
- Rectangles and “clouds” representing standardization and integration effort:
 - Color denotes level of burden. Green : low, yellow : intermediate, and red : high.
 - Size denotes the number of different sources to be standardized or integrated.
- Dashed lines denote a virtual database or portal.

In addition to showing the information flow paths to the WRAP Users, these high-level figures are meant to provide a means to compare the location and magnitude of burden of standardization and integration with respect to the WRAP data producers, WRAP users, and a potential data mediator (i.e., DataFed).

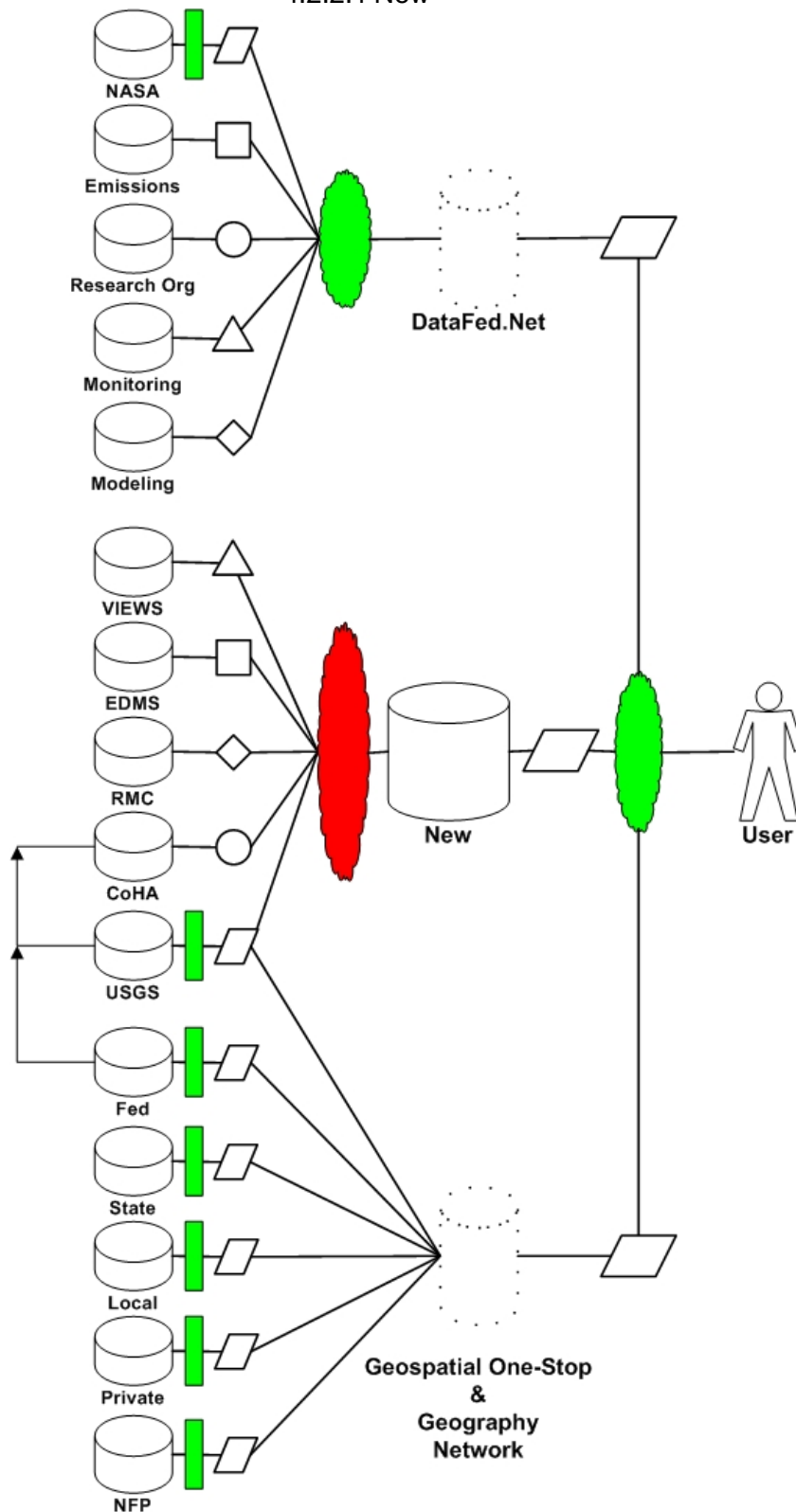
4.2.1 Status Quo – Integration by Users



- Largest integration burden on WRAP users.
- ~6 separate data streams for WRAP users to access.
- No standardization burden on WRAP nodes.
- WRAP data is directly accessed from data producers.

4.2.2 Centralized

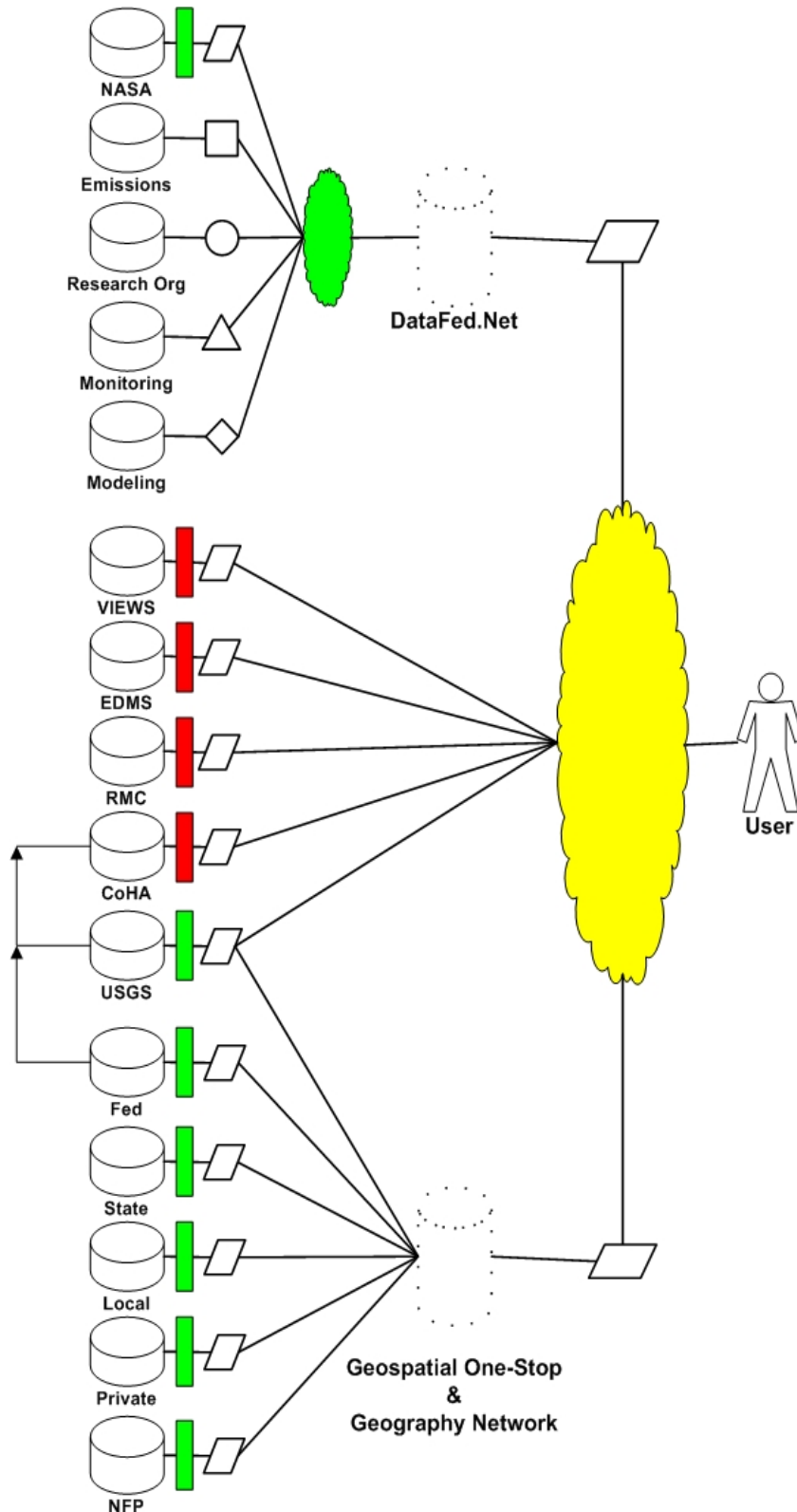
4.2.2.1 New



- “WRAP Centralized Regional Data Center” could be anywhere, including at EDMS or CoHA (DRI) location.
- Largest standardization and integration burden is at the centralized location.
- Small integration burden on the WRAP User.
- WRAP User only accessing 3 data streams.
- No standardization burden on the WRAP nodes (unless EDMS or CoHA is the “center”).
- Data in the centralized location is separated from the data stewards, which adds complexity to data maintenance (updates, additions, and deletions).

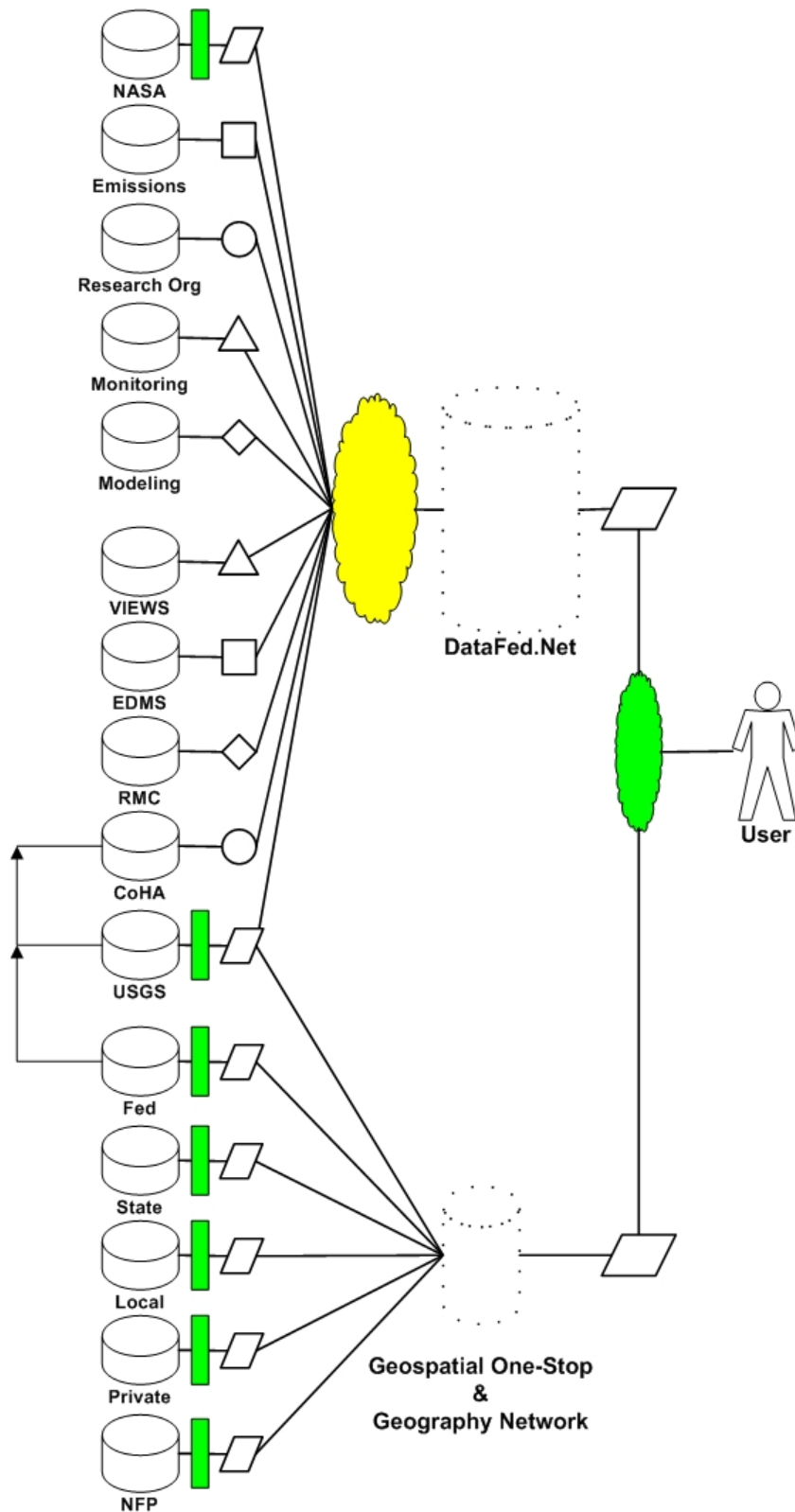
4.2.3 Distributed

4.2.3.1 Integration by Data Providers



- Standardization burden on WRAP data nodes.
- Integration burden still present at WRAP user level, though now all data is assessable through standardized interfaces and formats.
- WRAP user still has to deal with accessing 6 different data streams.
- WRAP data is directly accessed from data producers.

4.2.3.2 Integration by Data Mediator



- Larger standardization and integration burden on DataFed.
- No standardization burden on WRAP data nodes.
- Smallest integration burden on WRAP users –
- WRAP user only accessing 2 data streams.
- WRAP data is directly accessed from data producers.

4.2 Evaluation Criteria

	Evaluation Criteria:	Definition
System Properties	Flexibility for Future	Adaptable to new technologies (web-services, and service chaining), and to new WRAP mission(s).
	Institutional Stability	Component organizations are funded for the foreseeable future.
	Institutional Control	Component organizations are funded by WRAP.
	Extensible	aka "Robust" – changes to the existing system are not needed for new components (data, services, and tools) to be added.
	Allows measured approach for improving existing system	Can add new data streams, services, and tools one-by-one rather than needing to plan/accommodate/pay for all additions at once. Reduces risk.
	Ease of updates	Process for updating data, where keeping data in the hands of the data stewards is most efficient.
	Currency of data	Data is kept up to date either internally or by the original steward.
	System Complexity	Number of system components. Fewer is better.
User Needs	Flexibility in Data Output and analytical products (e.g., tabular, charts, XML)	Allows for data and information to be produced in a number of different formats to be ingested by WRAP Users as required.
	Richness of existing data types	Number and diversity of accessible data types if system went into operational mode today.
	Richness of existing tools / web services	Number and diversity of accessible tools and web services if system went into operational mode today.
	Small Integration Burden on Users	Users are unencumbered with standardization and integration tasks, and the number of data streams to access is kept to a minimum.
	Ease to Visual-Level Integration	Ease of getting to a point at which all data sources be integrated together (spatially and temporally) and viewed through a web-mapping application.
	Ease to Computational Integration	Ease of getting to a point at which all data sources be integrated together (spatially and temporally) & numbers crunched.
Costs	Capital Investment	Expenses for Hardware, Software. Smaller is better for all costs.
	Development Effort	Expenses for integration of hardware and software, and any special programming.
	Ongoing Maintenance Costs	Expenses for maintenance of system and data.
	Administrative Effort	Expenses to WRAP for administering contacts and system.
	Overall Costs	Total expenses to WRAP
	Implementation Timeline	Time it takes to for system to become operational. Sooner is better.

4.3 Option Evaluation

	Evaluation Criteria:	Status Quo	Centralized			Distributed w/ standards imposed on data providers	Distributed w/ data mediator
			New	Hosted at EDMS	Hosted at DRI		
System Properties	Flexibility for Future	C	A	B	C	B	A
	Institutional Stability	C	A	A	B	C	B
	Institutional Control	C	A	A	B	C	C
	Ease of adding components / apps and data sources - extensibility	D	B	C	C	C	A
	Allows measured approach for improvements to existing system	-	D	C	C	B	A
	Ease of updates	B	D	C	C	B	A
	Currency of data	B	D	C	C	B	A
	System Complexity / # of components	A	A/B	B	B	B	D
User Needs	Flexibility in Data Output and analytical products (e.g., tabular, charts, XML)	C	A	A	A	B	B
	Richness of existing data types	C	C	C	C	B	A
	Richness of existing tools / web services	C	C	C	C	B	A
	Small Integration Burden on Users	D	A	B	B	C	A
	Ease to Visual Integration	D	A	B	B	C	A
	Ease to Computational Integration	D	A	B	C	D	A
Costs	Capital Investment	A	D	C	C	A	A
	Development Effort	A	D	C	C	C	B
	Ongoing Maintenance Costs	C	D	C	C	B	A
	Administrative Effort	A	C	D	D	C	A
Implementation Timeline		A	C	C	C	C	A
Summary							
System Properties		2.4	2.7	2.8	2.3	2.6	3.3
User Needs		1.5	3.3	2.8	2.7	2.3	3.8
Costs		3.5	1.3	1.8	1.8	2.8	3.8
Implementation Timeline		4	2	2	2	2	4

D (1) = poor

C (2) = fair

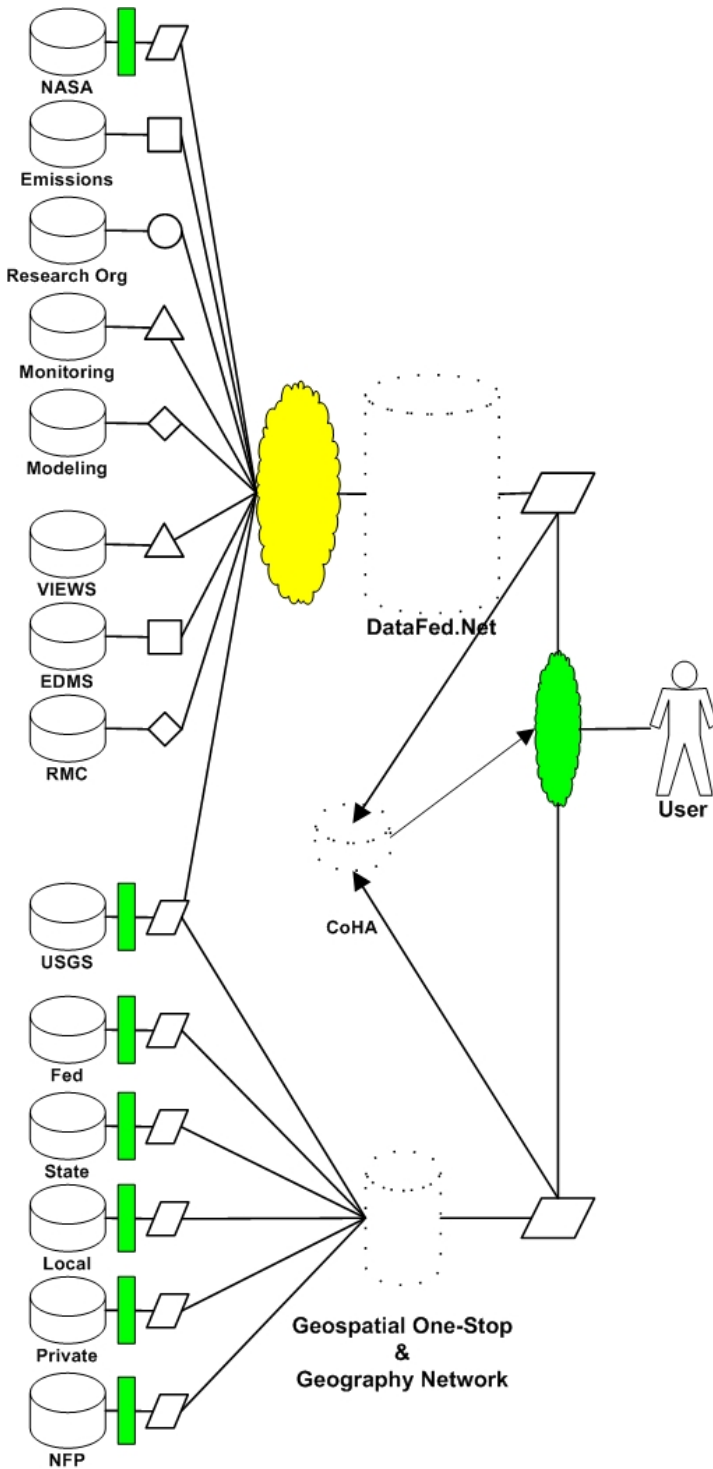
B (3) = good

A (4) = excellent

4.4 Recommendations

- 1) Take phased approach, and begin implementing low-cost and low-risk – but effective – recommendations first. These are the “low-hanging fruit”, which will not be affected by departures from the status quo system configuration.
- 2) Identify WRAP Geospatial Information Management Program Coordinator.
- 3) Form Geospatial Information Management Technical Working Group and conduct workshop. Include representatives from all WRAP data nodes and major projects.
- 4) Create simple catalog for all WRAP’s geospatial data and information resources. Provide basic description (metadata) including access information. Keep up-to-date and make available to WRAP user community.
- 5) Develop standardized site names and codes, time codes, filepath/filenames, and work towards semantic-level interoperability by developing controlled vocabularies.
- 6) Consider projection standards, data formats, interoperability standards.
- 7) Consider contract specifications and specific contract language, and apply as appropriate in relation to: 5 (above), and product-level metadata, and project-level metadata (DIF for registration in Global Change Master Directory).
- 8) Establish location-based cross-linkages through hypertext within existing WRAP project products, both between 2 or more WRAP project products (e.g., link characterizations of individual Class I Areas between CoHA and NEAR products), and between WRAP project products and other information resources (e.g., link characterizations of IMPROVE sites from within CoHA products to the detailed site descriptions and tools available within VIEWS and DataFed).
- 9) Establish a WRAP Geospatial Portal
- 10) Review all existing Needs Assessments to identify very specific information requirements for WRAP users including requirements relating to discovery, evaluation, and access. Specific tools and use cases not required at this time. If necessary, conduct additional needs assessment.
- 11) Select Option 4 for system configuration – using mediated data homogenization and integration for WRAP data streams, as appropriate. Phased (incremental) implementation is possible.
- 12) Begin phased data standardization and data integration efforts once system configuration option is decided upon.
- 13) Investigate cost-sharing possibilities from other air quality management organizations (e.g., RPO’s, <http://www.wrapair.org/wraplinks.htm>), and other information communities that may find need for integrated datasets or generic tools (e.g., WGA water program).
- 14) Conduct Needs Assessment for specific tools and use cases.

- 15) Reestablish and convene WRAP Data User group.
- 16) Consider scope, deliverables, and costs for CoHA, Attribution of Haze, and other upcoming projects as they relate to new opportunities for dynamically linking data and services, service chaining, virtual data centers, and virtual products. See diagram below:



Appendix A – Glossary

aggregation: Combining data to a lower-level of spatial and/or temporal specificity; the grouping together of a selected set of like entities to form a single entity. For example, grouping sets of adjacent areal units to form larger units.

ancillary data: Geodata that provides context to aid in the interpretation and provide meaning to other geodata or geospatial information.

aspatial: A term that is used to describe non-spatial data that is usually referenced to spatial data, for example, attributes.

attribute: A characteristic of a geographic feature described by numbers, characters, images and CAD drawings, typically stored in tabular format and linked to the feature by a user-assigned identifier (e.g., the attributes of a well might include depth and gallons per minute); a column in a database table.

auxillary: See ancillary (above).

browser: Web browser such as Netscape Navigator or MS-Explorer.

cache: A repository, usually temporary.

catalog: Listing of data resources and/or collection of metadata files.

chaining: An operation that binds a sequence of services where, for each adjacent pair of services, occurrence of the first action is necessary for the occurrence of the second action.

Class I Area: Areas of special national or regional natural, scenic, recreational, or historic value for which the Prevention of Significant Deterioration (PSD) regulations provide special protection. Under the Clean Air Act (CAA), three kinds of Class I areas either have been, or may be, designated. These are “Mandatory Federal Class I areas”, “Federal Class I areas”, or “Non-Federal Class I areas.”

Clearinghouse: A decentralized system of web servers, sponsored by the FGDC, that supports a detailed metadata catalog service with support for links to spatial data and browse graphics through the individual metadata files.

controlled vocabulary: A prescribed set of consistently used and carefully defined terms.

cross-walk: A table that maps the relationships and equivalencies between two or more metadata formats. Crosswalks or metadata mapping support the ability of search engines to search effectively across heterogeneous databases, i.e. crosswalks help promote interoperability.

data dictionary: A catalog of all data held in a database, or a list of items giving data names and structures. Also referred to as DD/D for data dictionary/directory. Commercial RDBMSs have online data dictionaries stored in special tables called system tables.

data mediation: A service that bridges that gap between the data provider and the data consumer; can include format standardization and possibly integration.

data node: An organizational component that produces and/or maintains a significant amount of geodata. For WRAP, this would include EDMS, VIEWS, RMC, and CoHA (DRI).

data steward: The party responsible for the maintenance of a database or data set.

database schema: A collection of items that model part or all of a real world object.

datum: A set of parameters and control points used to accurately define the three-dimensional shape of the Earth (e.g., as a spheroid). The datum is the basis for a planar coordinate system. For example, the North American Datum for 1983 (NAD83) is the datum for map projections and coordinates within the United States and throughout North America.

Dublin Core: A standard set of 15 metadata elements for cross-domain information resource description; intended to facilitate discovery of electronic resources.

entity: In cartography, a real world object that cannot be further subdivided into similar objects, for example a road, or a building. In relational databases, an entity is an object and its associated attributes.

entity relationship model: A logical way of describing entities and their relationships within relational databases. An entity-relationship model is often used in the conceptual design phase of creating a relational database and is usually expressed as a diagram showing the entities and the linkages that exist between them.

feature: Abstraction of a real-world phenomena, normally associated with a location relative to the Earth.

gateway: An annotated directory of web resources; any mechanism for providing access to another system.

geodata: A geospatial database or data set.

geographic information system: A system of capturing, storing, checking, integrating, analyzing and displaying data about the earth that is spatially referenced. Normally includes hardware, software, data, and humans.

geospatial: A property denoting a locational reference the Earth's surface.

hydrography: The description and study of bodies of water or their representations on a map.

integration: The vertical, horizontal, and temporal alignment of geospatial information that allows spatial and temporal relationships among 2 or more databases to be discerned. Integration can take place at two levels: visual and computational.

interoperability: The capability to communicate, execute programs, or transfer spatial data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units.

lattice: A surface representation that uses a rectangular array of mesh points spaced at a constant sampling interval in the x and y directions relative to a common origin.

metadata: In general, "data about data;" functionally, "structured data about data." Information about an information resource.

orthoimagery: A modified version of a perspective photograph of the earth's surface with distortions due to tilt and relief removed.

plot: A map containing both geospatial data and cartographic elements.

portal: Typically a "Portal site" has a catalog of web sites, a search engine, or both. A Portal site may also offer other services to entice people to use that site as their main "point of entry" (hence "portal") to a particular information community.

projection: The representation on a plane surface of any part of the surface of the earth.

raster: A regular division of space, i.e., a grid of cells covering an area.

registry: A system to provide management of metadata elements, data elements, or web services. Metadata registries are formal systems that provide authoritative information about the semantics and structure of data elements. Each element will include the definition of the element, the qualifiers associated with it, mappings to multilingual versions and elements in other schema.

resolution: The smallest spacing between two display elements; the smallest size of feature that can be mapped or sampled.

scale: The relation between the size of an object on a map and its size in the real world.

spatial data infrastructure (SDI): An integrated, on-line network that delivers geospatial data, services and information for applications, better business and policy decision-making, and value-added commercial activities.

spheroid: Part of the mathematical model that describes the shape of the earth.

toponymy: A dataset which includes the names of geographic features, normally used for cartographic (map) product.

vector: Refers to potentially irregular divisions of space, based upon points; points can form lines, and lines can form polygons.

web mapping: A type of web service that provides static or interactive maps over the Internet.

web service: A network-based, distributed, modular component that performs specific tasks, and conforms to a specific set of technical specifications that make it interoperable with compatible components.

Glossary Acknowledgements:

The *GIS Dictionary*, by the Association for Geographic Information, <http://www.agi.org.uk/resources/index.htm>, accessed 25 May 2004.

The *Dublin Core Metadata Glossary*, by the Dublin Core User Guide Committee <http://dublincore.org/documents/2001/04/12/usageguide/glossary.shtml>, accessed 25 May 2004.

The ESRI *Glossary of GIS Terms*, <http://www.esri.com/library/glossary/glossary.html>, accessed 25 May 2004.

Appendix B – List of Acronyms

AoH - Attribution of Haze [Project]

ASCII - American Standard Code for Information Interchange

CAPITA - Center for Air Pollution Impact & Trend Analysis

CDX - Central Data Exchange

CENRAP - Central Regional Air Planning Association

CGDI - Canadian Geospatial Data Infrastructure

CIRA - Cooperative Institute for Research in the Atmosphere

CoHA - Causes of Haze Assessment [Project]

CSDGM - Content Standard for Digital Geospatial Metadata

DIF - Directory Interchange Format

DRI - Desert Research Institute

EDMS - Emissions Data Management System

ESRI - Environmental Systems Research Institute

FAQ - Frequently Asked Questions

FGDC - Federal Geospatial Data Committee

GCMD - Global Change Master Directory

GIS - geographic information system

GML - Geographic Markup Language

GOS - Geospatial One-Stop

GSDI - Global Spatial Data Infrastructure

GSM - General Service Model

HTML - hyper-text markup language

IMPROVE - Interagency Monitoring of Protected Visual Environments

INEGI - Instituto Nacional de Estadística, Geografía e Informática

ITEP - Institute for Tribal Environmental Professionals

ISO - International Organization of Standards

NEI - National Emissions Inventory

NIF - NEI Information (file) Format

NSDI - National Spatial Data Infrastructure

OGC - OpenGIS Consortium

RMC - Regional Monitoring Center

RPO - Regional Planning Organization

SDI - spatial data infrastructure

SIP - State Implementation Plan

SLD - Style Layer Descriptor

TIP - Tribal Implementation Plan

TRI - Toxic Release Inventory

UML - unified modeling language

URL - Universal Resource Locator

USGS - United States Geological Survey

IEWS - Visibility Information Exchange Web System

WIGIMS - WRAP Integrated Geospatial Information Management Strategy

WCS - Web Coverage Service

WFS - Web Feature Service

WMS - Web Mapping Service

WRAP - Western Regional Air Partnership

XML - Extensible Markup Language